

Proton Cancer Therapy Facilities in the U.S. - Status on Evaluation for Electronics Radiation Testing

Kenneth A. LaBel (and a cast of 1000's)

ken.label@nasa.gov

301-286-9936

Co- Manager, NEPP Program

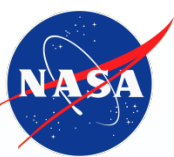
NASA/GSFC

<http://nepp.nasa.gov>

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Acronyms

| Acronym | Definition |
|---------|---|
| CNL | Crocker Nuclear Lab |
| GSFC | Goddard Space Flight Center |
| HUPTI | Hampton University Proton Therapy Institute |
| IAI | Integrity Applications Incorporated |
| ITAR | International Traffic in Arms Regulations |
| IUCF | Indiana University Cyclotron Facility |
| LBNL | Lawrence Berkeley National Laboratories (LBNL) |
| LLUMC | Loma Linda University Medical Center (LLUMC) |
| NASA | National Aeronautics and Space Administration |
| NEPP | NASA Electronic Parts and Packaging |
| NSRL | NASA Space Radiation Laboratory |
| PTCOG | Particle Therapy Co-Operative Group |
| SCCA | Seattle Cancer Care Alliance |
| TRIUMF | Tri-University Meson Facility |
| UCD | University of California at Davis |
| UFHPTI | University of Florida Health Proton Therapy Institute |



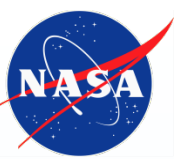
Indiana University Cyclotron Facility (IUCF) Closure

- IUCF has been the most used higher energy proton test facility for most of the U.S. space industry (electronics).
 - It is primarily a medical facility that NASA and others have supported to develop a parallel capability for proton testing of electronics.
 - *~2000+ hours of use per year for electronics testing*
 - IUCF closed to the Space Community Usage on Oct 31, 2014.
 - High energy Proton Test (>200 MeV) is Critical to Space Community.
- Ad hoc U.S. government team formed to investigate options.
 - Existing proton SEE test facilities (North America).
 - Explore access to newer proton cancer therapy sites.
- Study began in 2014-Oct.



Existing North American Proton Facilities

- **Tri-University Meson Facility (TRIUMF) – Vancouver, Canada**
 - Challenges with “border crossing” and limited “cycles” of availability
 - *TRIUMF is now “ITAR compliant”*
- **Massachusetts General Hospital (MGH) Francis H. Burr Proton Therapy Center (additional access limited beyond current beam amounts),**
- **University of California at Davis (UCD) Crocker Nuclear Lab (CNL),**
 - Lower prime energy (63 MeV) does not meet all test requirements
- **Lawrence Berkeley National Laboratories (LBNL) – (50 MeV) has similar technical challenges as CNL, and,**
- **Loma Linda University Medical Center (LLUMC) and NASA Space Radiation Laboratory (NSRL) – have pulsed beam structures and other technical considerations.**



Team Members

(min. 1 site visit or significant consulting)

- **NASA**
 - Ken LaBel, Chuck Foster (consultant)
- **The Aerospace Corporation**
 - Tom Turflinger, Andy Kostic, Rich Haas, Jeff George, Steve Moss
- **Integrity Applications Incorporated (IAI)**
 - Brian Wie
- **Vanderbilt University**
 - Robert Reed
- **Boeing**
 - Jerry Wert, Sudhakar Shetty
- **BAE Systems**
 - Reed Lawrence, John Davis
- **Jet Propulsion Laboratory**
 - Steve Guertin



Ad Hoc “Team” Plan – Proton Therapy Sites

- ✓ **Contact facilities (focus on cyclotrons)**
- ✓ **Site visit to determine interest**
 - Technical
 - Access
 - Business case
- ☐ **Beta/shakeout tests at interested sites to determine usability**
 - ☐ Underway
- ☐ **Work logistics of access**
 - ☐ Underway
- **Determine guidelines for usage of these sites**
- **Recommendations for modifications and longer term access.**
 - TBD.

Assumption: Facilities will have available 300-500 hours/year each (weekends).
Multiple facilities required to replace IUCF in the near term.



Background: Proton Beam Delivery

- There are two types of facilities being used for proton cancer therapy:
 - Cyclotrons, and,
 - Synchrotrons.
- In addition, there are three types of beam delivery methods used.
 - Scatter,
 - Wobble/uniform scan, and,
 - Pencil beam scan.
- *IUCF was a **cyclotron** and utilized a **scatter** beam delivery system.*
 - *Other options require thought and consideration for possible use.*



Basic Study Requirements

- **Energy range:**
 - 125 MeV to > 200 MeV
- **Proton flux rates:**
 - $1e7$ p/cm²/sec to $1e9$ p/cm²/sec
- **Test fluences:**
 - $1e9$ p/cm² to $1e11$ p/cm²
- **Irradiation area:**
 - Small (IC ~ 1cm) to Large > 15cm x 15cm
- **Beam uniformity:**
 - >80%
- **Beam structure:**
 - Cyclotron preferred (random particle delivery over time)
 - Fixed spot or scatter (random particle delivery over area)

Proton Facility Status (200 MeV – North America)

| Facility | | Location | Hourly Rate | Type | Access/ Annual Hours | Expected Avail. | Shakeout Test |
|---------------------------------------|---|------------------|------------------------------------|-------------|--|-----------------|---------------|
| Future Facilities | Northwestern Medicine Chicago Proton Center | Warrenville, IL | TBD | Cyclotron | 2 hrs – weeknights 8-16 hrs Saturdays | Now | Yes |
| | Scripps Proton Therapy Center | La Jolla, CA | TBD | Cyclotron | Up to 500 hrs | Now | Yes |
| | Seattle Cancer Care Alliance Proton Therapy - ProCure | Seattle, WA | TBD | Cyclotron | TBD | CY16? | Yes |
| | Hampton University Proton Therapy Institute (HUPTI) | Hampton, VA | TBD | Cyclotron | TBD weekends (up to 32 hrs?) | CY15 | Planned |
| | OKC ProCure Proton Therapy Center | OKC, OK | \$1000 + one-time \$3000 setup fee | Cyclotron | Weekdays 6 hrs + possible shared time Saturdays 5-8 hrs | CY15 | TBD |
| | University of Florida Health Proton Therapy Institute (UFHPTI) | Jacksonville, FL | TBD | Cyclotron | Weekend days (possibly shared with quality assurance) | CY15 | TBD |
| | Provision Center for Proton Therapy | Knoxville, TN | TBD | Cyclotron | TBD | TBD | TBD |
| | Dallas Proton Treatment Center | Dallas, TX | TBD | Cyclotron | TBD | CY16? | TBD |
| | University of Maryland Proton Treatment Center | Baltimore, MD | TBD | Cyclotron | 500 | CY16? | TBD |
| Existing Facilities | Tri-University Meson Facility (TRIUMF) | Vancouver, CAN | \$750 | Cyclotron | 4x/year | Yes | N/A |
| | Slater Proton Treatment and Research Center at Loma Linda University Medical Center (LLUMC) | Loma Linda, CA | \$1,000 | Synchrotron | ~1000 | Yes | N/A |
| | Mass General Francis H. Burr Proton Therapy (MGH) | Boston, MA | \$650 | Cyclotron | ~800 hours 12hr weekend days, 2 of 3 weekends | Yes | N/A |
| | NASA Space Radiation Lab (NSRL) | Brookhaven, NY | \$4,700 | Synchrotron | ~1000 hours | Yes | N/A |
| Indiana University Cyclotron Facility | | Bloomington, IN | \$820 | Cyclotron | 2000 hours | No | N/A |



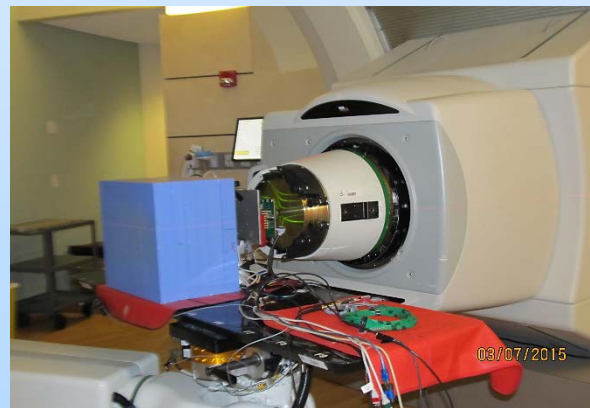
Challenges Identified with Using Proton Therapy Facilities

- **Technical**

- Beam structure and delivery are mostly different than we are used to. *This is the largest technical concern.*
- Independent dosimetry required for SEE testing – flux, fluence and uniformity.
- Beam intensity control: translation between SEE test parameters and tumor delivery.
- Beam stops required (therapy “stops” beam in patient).
- Radiation dosage limits may impact some higher fluence tests.
- Remote-controlled movement of test article mounting stage may not exist at all sites – time hindrance.

- **Logistics**

- Access
- Scheduling
- Cost



*Shakeout testing at Cadence Health Proton Center,
Warrenville, IL*



Special Session Held at Single Event Effects (SEE) Symposium – May 20, 2015 in La Jolla, CA

- **Special Session: SEE Testing and Proton Therapy Centers: A New Paradigm**
 - Co-chairs: Tom Turflinger, Brian Wie, Robert Reed
 - Proton Therapy “coordinators”: Dr. Mark Pankuch (Cadence), Dr. Lei Dong (Scripps)
- **Abstract:**
 - With the closure of the most popular U.S.-based high energy proton SEE test facility (Indiana University Cyclotron Facility – IUCF), the community requires new locales for testing. This special session is focused on:
 - The investigation by an Ad Hoc Government Team that’s been formed to explore the use of proton cancer therapy centers across the U.S. not currently used for SEE testing;
 - Status on existing North American proton facilities, and,
 - Discussion with some of the therapy centers for access options.
- **We were fortuitous that a meeting was being held in parallel with SEE-MAPLD in San Diego:**
 - Particle Therapy Co-Operative Group (PTCOG).
- **Thanks also to Ethan Cascio for providing “guide” for new entrants from cancer therapy side.**
- **<http://seemapld.org>**



The Next Proton Steps

- **Shakeout test schedule**
 - **Tests completed**
 - Seattle Cancer Care Alliance (SCCA)
 - Northwestern Medicine Chicago Proton Center (formerly Cadence Health)
 - Scripps Proton Therapy Center
 - **Tests Planned**
 - Hampton University Proton Therapy Institute (HUPTI) - June/July
 - TBD: Oklahoma City ProCure Proton Therapy Center, University of Florida Health Proton Therapy Institute (UFHPTI), ProNova/ProVision
 - CY16-17: University of Maryland Proton Treatment Center, Dallas Proton Treatment Center
- **Contracts, consortia, and consolidator**
 - **Still working initial interactions and approaches.**
 - Most facilities will take purchase orders, but may only want users who test on a regular basis
 - **Consolidators and Consortia approaches were brought up in discussion with therapy centers.**
- **Long term - TBD**



Proton Thoughts

- **Several facilities have stated wanting only those users who will utilize facility on regular basis.**
 - Minimizes interference with medical priorities/contracts.
 - Impact to “occasional” user.
- **Proton therapy sites might Consolidator in a manner somewhat similar to Berkeley Cyclotron and The Aerospace Corp in the “old days”**
 - ISDE schedules access and provides an “expert” to interface between the users and the facility. I.e., train users how to use each facility.
 - This minimizes headaches for medical facilities not wanting the hassle of “newbies”.
 - TBD implications.
- **Independent beam dosimetry needed**
 - Team is evaluating options but leaning toward ion chamber and Gafchromic film in concert.
 - Copy needed at each therapy site.



Current Recommendations for Proton Testing*1

| Type of Test | Cyclotron | Synchrotron | Fixed or Scatter | Wobble/Uniform Scan | Pencil Beam Scan |
|--|-----------|-------------|------------------|---------------------|------------------|
| Static test (Biased, non-clocked) | X | X | X | X | X |
| Destructive event test | X | X | X | X | X |
| Dynamic test (device with low proton sensitivity or slow operation) - example, commercial flash memory | X | X | X | X | X |
| Dynamic test (high proton sensitivity or fast operation) - example, Intel 14nm processor*2 | X | | X | | |
| System test (board/box level) - example, commercial motherboard | X | | X | | |

***1 - Assuming energy, flux, fluence, uniformity, etc... are met.**

***2 - Timing dependent tests (dynamic operations) especially on very proton sensitive devices require careful thought for using other than an IUCF-like beam (a cyclotron with a scatter mode). Further work is needed to evaluate useful nature of scan beam delivery for these kinds of tests.**



Protons – The Future

- **Access/contracts/technical logistic “headaches” for cancer centers must be minimized to allow widest use for radiation effects research.**
 - **We are NOT their prime customer.**
 - **Long-term access hinges on three items:**
 - **Minimum invasiveness of our community on cancer therapy sites (technical, logistics),**
 - **Business model (for cancer therapy sites), and,**
 - **Medical usage not expanding to use “spare time” – insurance and doctor access are current limits, but may be changing.**